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Monitoring Kittlitz's and Marbled Murrelets in Glacier Bay National Park and Preserve

2011 Annual Report

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Executive Summary

Since 2009, the National Park Service's Southeast Alaska Inventory and Monitoring Network (SEAN) has monitored population abundance and trend of Kittlitz's (KIMU) and marbled murrelets (MAMU) in Glacier Bay National Park and Preserve, an important summer residence for both species. Annual reports concisely summarize each survey's results, focusing on population abundance and spatial distribution.

Monitoring focuses on KIMU, with secondary consideration of MAMU. KIMU are a summer resident, open-water, pursuit forager whose reliance on pelagic prey sources link their habitat use in some areas to dynamic environmental variables such as glacial extent and ocean productivity. Previous studies in Glacier Bay and the region have suggested declines in KIMU populations, but large uncertainty persists because of sparse data and methodological differences. SEAN uses boat-based line transect surveys to estimate species-specific, on-water density and abundance of murrelets, accounting for detection probability and unidentified murrelets.

We surveyed 258 km on 46 transects during 5-16 July 2011 across the 1,170 km^2 survey area. Our estimated KIMU abundance of 7,477 (SE = 1,119) was ~50% lower than estimates from 2009 and 2010. Estimated MAMU abundance of 73,766 (SE = 7,055) matched high estimates from 2010. We urge caution in interpreting change in KIMU abundance estimates. The decrease does not necessarily reflect intrinsic population change, as many factors relating to high spatial and temporal variation in murrelet populations could also have contributed. KIMU were diffusely distributed across the survey area, with some moderate concentrations in protected inlets and the upper arms of the bay. However, most KIMU were not closely associated with tidewater glaciers or glacial outflow. MAMU occurred in significant numbers throughout the survey area, but very large concentrations near the mouth of the bay suggested a large daily influx of transient birds to forage in the bay.

Abundance estimates for both species were higher than reported from 1999 to 2003, although the extent to which changes reflect differences in methods is uncertain. Glacier Bay is a significant breeding season population center for both species, with KIMU likely comprising an important fraction of the global population. Glacier Bay hosts very large overlapping concentrations of KIMU and MAMU relative to approximate global population sizes.

Acknowledgments

Introduction

Since 2009, the National Park Service's Southeast Alaska Inventory and Monitoring Network (SEAN) has monitored abundance and trend of Kittlitz's (*Brachyramphus brevirostris*, hereafter "KIMU") and marbled murrelet (*B. marmoratus*, hereafter "MAMU") populations in Glacier Bay National Park and Preserve. The program arose from concerns over apparent regional and local KIMU population declines, their status as a candidate species for protection under the Endangered Species Act (USFWS 2013), and the hypothesis that KIMU populations respond to fluctuations in drivers of the Glacier Bay ecosystem such as glacial extent and ocean productivity.

The KIMU is a seabird endemic to Alaska and northeastern Russia, with the largest breeding populations in the northern Gulf of Alaska (Day et al. 1999, USFWS 2013). As a summer resident, open-water, pursuit forager, KIMU play an important role as integrators of variation in marine and terrestrial ecosystems and directly relate to the conceptual ecological models in the SEAN Vital Signs Monitoring Plan (Moynahan et al. 2008). In summer, KIMU are often associated with glacially-influenced habitats, commonly foraging near glacier outflows (Day and Nigro 2000, Kuletz et al. 2003, Arimitsu et al. 2011, Kissling et al. 2011, Madison et al. 2011) and nesting in recently de-glaciated areas with sparse vegetation (Day 1995, USFWS 2013). Reliance on pelagic prey sources and glacially-influenced habitats link KIMU to dynamic habitat conditions such as glacial extent and ocean productivity that may be influenced by climate change (e.g., Arendt et al. 2002).

Prior studies in Glacier Bay and the region have suggested declines in KIMU breeding season populations, but uncertainty remains because of sparse data, high variability in estimates, and differences in methods (Hoekman et al. 2011b, c; Kuletz et al. 2011a, b; Piatt et al. 2011, USFWS 2013, Kirchhoff et al. In Press). Several challenges inherent to Glacier Bay and its murrelet populations complicate estimating murrelet population abundance: difficulty distinguishing between the two cryptic species, incomplete detection of murrelets along transects, large spatial and temporal variation in populations, and convoluted topography that complicates survey transect placement.

SEAN monitoring focuses on estimating breeding season population abundance and trend primarily for KIMU and secondarily for MAMU. Boat-based line transect surveys are conducted during early July across a survey area covering >90% of Glacier Bay proper. The 2009 and 2010 annual KIMU monitoring reports, in conjunction with the final long-term monitoring protocol (Hoekman et al. 2013), provide complete protocol development details and fully describe monitoring methods.

Annual monitoring reports are designed to efficiently report results in a simple and concise format, focusing on population abundance and spatial distributions. Periodic syntheses at 6 year intervals will assess program performance and population trends. Our 2011 study objectives were to continue the third year of surveys, estimate population abundance for KIMU and MAMU in the Glacier Bay and describe their spatial distribution, and summarize results since 2009.

Methods

This methods section includes a brief overview of survey design, survey methods, and analytic methods. Full details can be found in the SEAN long-term monitoring protocol (Hoekman et al. 2013); relevant protocol sections are referenced below.

Study area

Glacier Bay is a narrow, glacial fjord located in southeast Alaska. The study area encompassed 1,170 km^2 of waters north of Icy Strait and excluded some areas designated as non-motorized waters or those that did not allow safe survey vessel passage (Figure 1).

See Chapter 1 of the SEAN long-term monitoring protocol for more detail (Hoekman et al. 2013).

Survey design

We employed a generalized random tessellation stratified sampling design (Stevens and Olsen 2004), which minimized deleterious effects of large spatial variation in murrelet abundance (Hoekman et al. 2011a) by providing a random, spatially-balanced sample. We allocated survey effort relative to expected densities of KIMU using unequal probability sampling. To avoid placing transects parallel to the observed density gradient of murrelets relative to water depth (Drew et al. 2008, Kirchhoff 2011) and to provide representative coverage across water depths, we oriented linear transects perpendicular to the local prevailing shoreline and zigzag transects from shore-to-shore. Zigzag transects served to avoid undesirably short transects in enclosed waters. Transects are sampled according to an augmented, serially alternating panel design (McDonald 2003), where one panel (set of transects) is sampled annually and three others are visited on a three-year rotation, with 2011 including the second panel.

See Chapter 2 and Appendix B of the long-term monitoring protocol for more detail (Hoekman et al. 2013).

Figure 1. Line transects surveyed for murrelets in July 2011. Permanent (red lines) and Panel 2 (blue) transects were surveyed as part of an augmented, serially alternating panel design with a three-year rotation. Linear transects were used in open waters (> 2.5 km wide) and zigzag transects were used in more restricted waters. Transects extended from shore to shore, except where some were split into 2 at mid-Bay to maintain optimal transect length. Linear transects were oriented perpendicular to the prevailing shoreline; orientation of zigzag transects relative to shore was determined by width of each area. Unsampled areas are highlighted in light blue.

Survey methods

We conducted boat-based line transect surveys (Buckland et al. 2001) at a speed of ≤10 km/h aboard the NPS R/V Fog Lark, an 8.5 m landing craft with a large front deck that provided a viewing height of approximately 3 m above the water line for two observers. For all groups (murrelets of one species class in a flock) initially located on the water, observers recorded count, species class (KIMU, MAMU, or unidentified), and estimated distance and orientation from the boat. The allowable Beaufort sea state was ≤ 2. Program NPTransect (designed by R. Sarwas and W. Johnson, National Park Service) was used to record observations and associated GPS-based date/time/location stamps.

See the long-term monitoring protocol (chapter 3 of the narrative, Standard Operating Procedures, hereafter "SOPs," 1, 2, 3, and 9, and Appendix F) for more detail (Hoekman et al. 2013).

Abundance estimation

We estimated detection probability and group size using Program DISTANCE version 6.0 (Thomas et al. 2010) and species-specific abundance using statistical software R version 2.13.0 (R Development Core Team 2008) following recommended distance sampling methods (Buckland et al. 2001) and protocol SOP 12 (Hoekman et al. 2013). We modified distance sampling methods to account for incomplete detection near the transect center line and unidentified murrelets. Adjustments for unidentified murrelets assumed that species were correctly identified and that the proportions of each species in the identified and unidentified samples were the same. Density estimates were based on several component parameters: detection probability across the transect width, detection probability near the center line, group size for each species class, and encounter rate for each species class. We estimated abundance by multiplying total survey area (1,170 km^2) by estimated densities.

See Hoekman et al. 2011b and the monitoring protocol (appendices A and D, SOPs 11 and 12) for more detail.

Results

We surveyed 46 transects totaling 258 km between 5-16 July 2011 and detected 1,933 groups. We classified 275 (14%) groups as KIMU, 1,282 (64%) as MAMU, and 436 (22%) as unidentified. Detection probability was high within 230 m of the transect center line (70%; Table 1), and our estimated effective strip width was 160 m. Estimated detection probability remained near 1 to approximately 60 m from the center line, decayed rapidly at intermediate distances, but remained moderately high even at larger distances (Figure 2). Twenty percent of all observations were made during Beaufort sea state 0, 75% at 1, and 5% at 2. Most observations (75%) were recorded during cloudy conditions (>50% cloud cover), but only 1% during rainy weather.
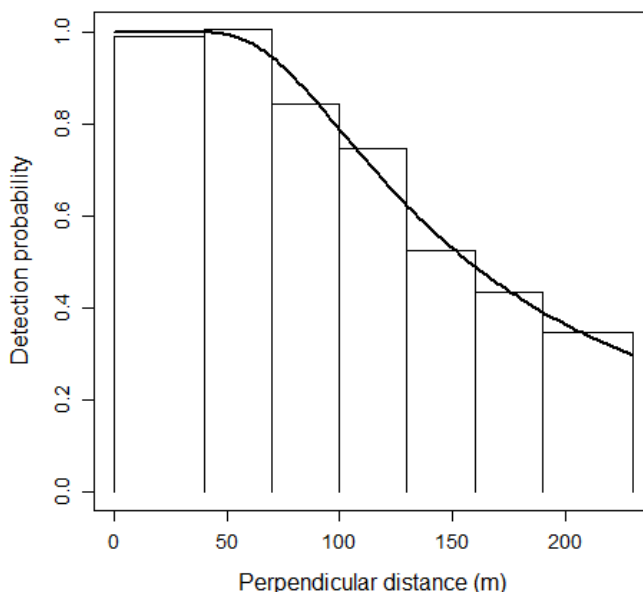

Figure 2. Estimated detection function for murrelets from line transect surveys in Glacier Bay, July 2011, illustrating detection probability of murrelet groups relative to the perpendicular distances from the transect center line.

Much higher average group size and encounter rates for MAMU (Table 1) resulted in estimates of density and abundance approximately10 times higher than KIMU (Table 2). Precision of estimated abundance was higher for MAMU (CV = 0.096) than KIMU (CV = 0.150).

KIMU were diffusely distributed throughout Glacier Bay (Figure 3). The largest concentrations of KIMU were encountered in the west arm, specifically around the outlet of Scidmore Bay, Reid Inlet, Composite Island, and the west side of Russell Island. KIMU were relatively rare in mid- and lower-bay transects. MAMU were relatively common on almost all transects, but were especially concentrated in the lower bay, from Strawberry Island south to the mouth of the bay (Figure 4).

Table 1. Component parameter values used to estimate on-water density and abundance of Kittlitz's and marbled murrelets in Glacier Bay for July 2011. Group sizes were estimated as averages or from a regression accounting for a potential influence of group size on detection; one estimate was selected for each species class (see SOP 11 of protocol for more detail).

Parameter	Estimate	SE	*P*-value	Degrees of freedom
Detection across transect width	0.70	0.02		1,874
Detection near transect center line	0.94	0.03		66
Group size: Average				
Kittlitz's murrelet[a]	1.68	0.07		243
Marbled murrelet	2.94	0.08		1,227
Unidentified murrelet	3.96	0.34		373
Group size: Regression estimate				
Kittlitz's murrelet	1.76	0.06	0.997	242
Marbled murrelet[a]	2.73	0.05	0.015	1,226
Unidentified murrelet[a]	3.02	0.14	0.013	372
Encounter rate (groups/km)				
Kittlitz's murrelet	0.87	0.12		44
Marbled murrelet	5.29	0.47		44
Unidentified murrelet	1.65	0.16		44

[a] Estimate selected for estimation of density and abundance.

Table 2. Estimates of on-water population density and abundance of Kittlitz's and marbled murrelets in Glacier Bay during early July. Abundance was projected across surveyed waters only. Note that pilot surveys in 2009 (Hoekman et al. 2011a) differed in survey area (1,092 km^2) and methods.

	Kittlitz's murrelet				Marbled murrelet			
Year	Density[a]	SE	Abundance	SE	Density[a]	SE	Abundance	SE
2011	6.4	1.0	7,477	1,119	63.1	6.0	73,766	7,055
2010	11.4	1.2	13,308	1,357	52.7	4.6	61,717	5,372
2009	12.0	3.7	13,124 [b]	4,062	26.5	3.7	28,978[b]	4,077

[a] Individuals/km^2

[b] Abundance extrapolated over 1,092 km^2 of sampled waters; all others extrapolated over 1,170 km^2.
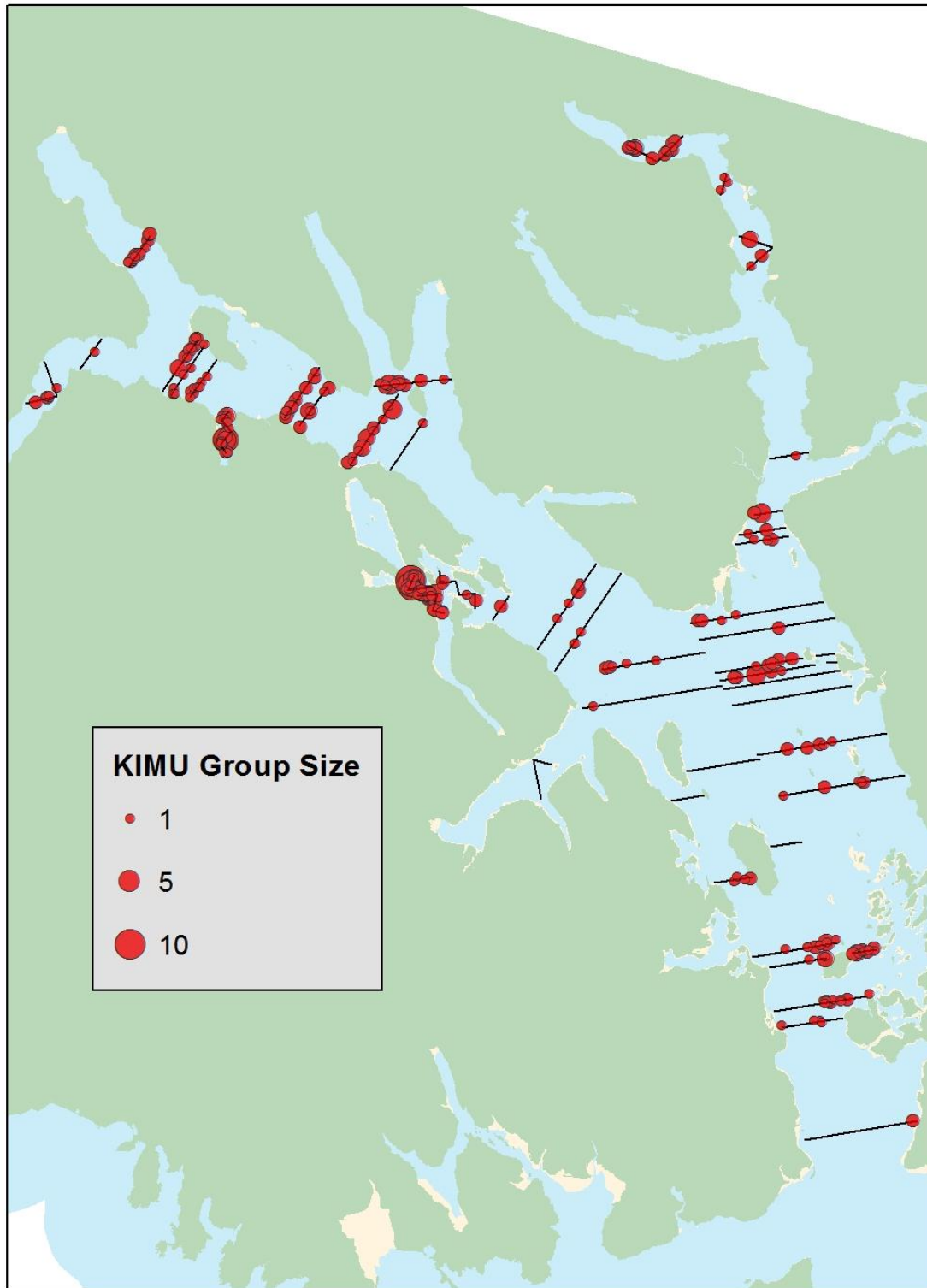
Figure 3. Spatial distribution of Kittlitz's murrelets observed during line transect surveys (black lines) in Glacier Bay, July 2011. The area of symbols is proportional to group size.
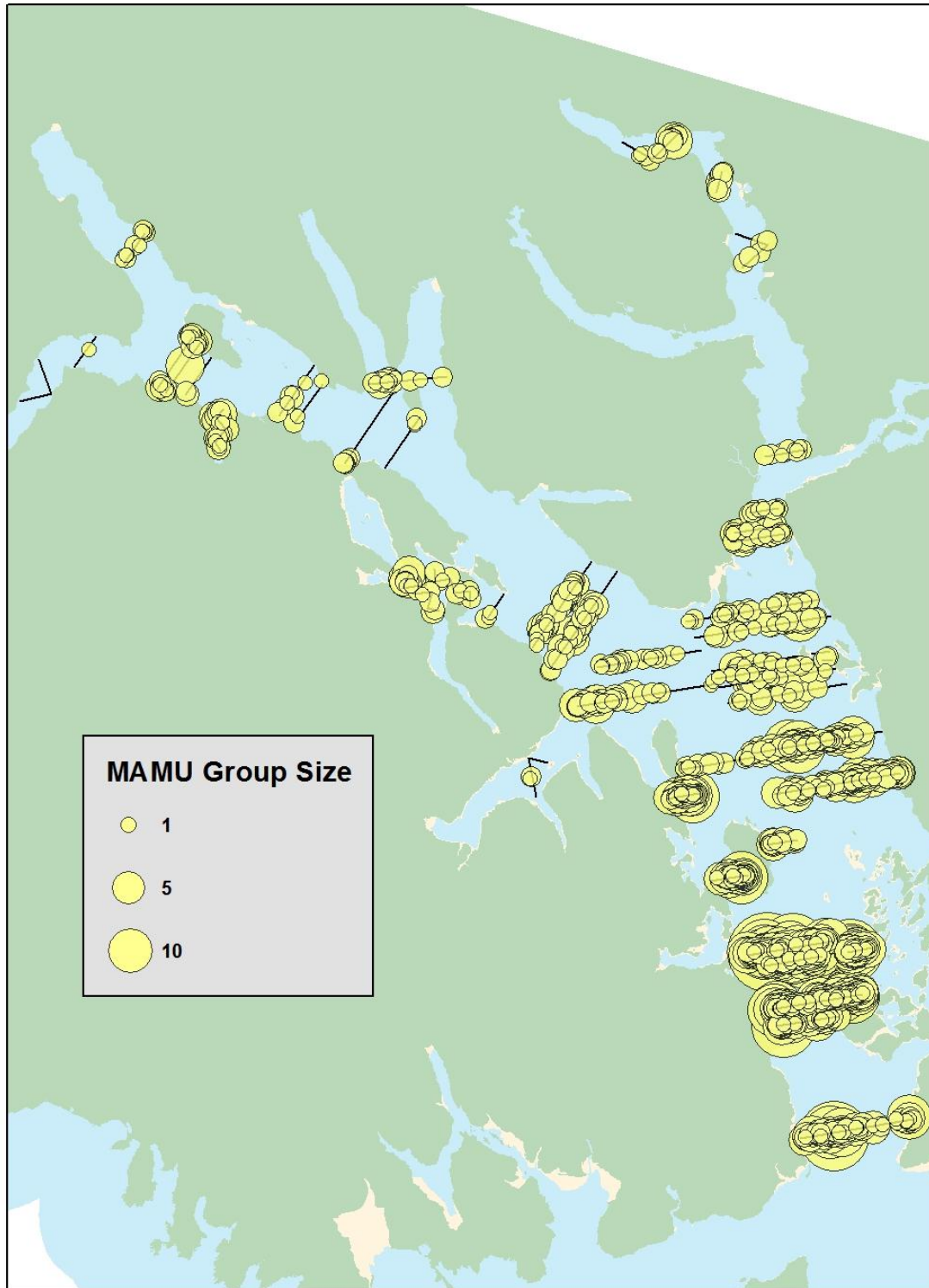
Figure 4. Spatial distribution of marbled murrelets observed during line transect surveys (black lines) in Glacier Bay, July 2011. The area of symbols is proportional to group size.

Discussion

Density and abundance

Estimated on-water abundance of *Brachyramphus* murrelets in our survey area (~81,000) during July matched the very high level seen in 2010, but estimated abundance of KIMU was ~50% lower than in 2009 and 2010 (Table 2; Kirchhoff and Lindell 2011; Hoekman et al. 2011a,b). Despite this change, estimated KIMU density (6.4 individuals/km^2) in Glacier Bay remained substantially higher than from line transect surveys in 2007 (3.4; Kirchhoff 2008) and 2008 (4.5; Piatt et al. 2011) and from strip transect surveys from 1999-2003 (range 1.8-5.0; Piatt et al. 2011), although strip transects likely under-estimate density. Our 2011 abundance estimate equaled or exceeded those from other important breeding areas in Alaska (Arimitsu et al. 2011; Day et al. 2011; Kissling et al. 2011; Kuletz et al. 2011a, b; Madison et al. 2011; Piatt et al. 2011), indicating that Glacier Bay contains a regionally important breeding population that likely comprises a significant fraction of the global population (USFWS 2010).

The large difference between 2010 and 2011 KIMU abundance estimates was unlikely to reflect only intrinsic population change. Annual variability in KIMU population estimates typically has been high (Kissling et al. 2011; Piatt et al. 2011) and could also be affected by factors that are difficult to assess, such as numbers of birds nesting, immigration and emigration to and from the local population, variation in numbers and movements of non-breeding birds, and short-term movement of birds within the survey area. Murrelets during the breeding season exhibit ephemeral concentrations, and whether one or more of these "hotspots" happen to be sampled can dramatically influence population estimates (Romano et al. 2007, Day et al. 2011, Hoekman et al. 2011a). Therefore, we recommend caution in interpreting change in KIMU population estimates in 2011 and potential causes.

In contrast, estimated on-water density and abundance of MAMU in 2011 were the highest on record for Glacier Bay. MAMU have been more numerous than KIMU in Glacier Bay, but MAMU density estimates from strip transects during 1999-2003 were relatively low (range 6.4-9.9 individuals/km^2; Drew et al. 2008). Densities from strip and line transects surveys were intermediate from 2007 to 2009 (range 11.0-26.5; Kirchhoff 2008, Kirchhoff et al. 2010, Piatt et al. 2011) before densities ≥ 53 individuals/km^2 were reported for line transect surveys in 2010 and 2011 (Table 2; Kirchhoff and Lindell 2011). The magnitude of these increases appears far more than can be attributed to differing survey methods (e.g., Hoekman et al. 2011b).

Although Alaska MAMU populations may be near 1,000,000 individuals (Piatt et al. 2007), our recent estimates indicate that Glacier Bay now contains an increased and significant breeding season population. The size of MAMU populations generally decreases in other KIMU breeding population centers to the west of Glacier Bay (Arimitsu et al. 2011; Kissling et al. 2011; Kuletz et al. 2011a, b; Madison et al. 2011), which appears to host the largest overlapping concentrations of these species. Glacier Bay appears to provide high quality marine habitat and foraging resources for both species, which demonstrate high spatial and temporal overlap (Day et al. 1999, Day and Nigro 2000). The historically high MAMU abundance in 2011 also implied that the smaller KIMU population estimate

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could not readily be attributed to decreased prey abundance, although availability may have differed between species. High spatial overlap of these species in Glacier Bay also highlights the challenge of monitoring KIMU populations coexisting with the morphologically-similar but much more abundant MAMU (Hoekman et al. 2011c).

Spatial distributions of populations

Unlike 2009 and 2010 surveys, when large KIMU "hotspots" were evident in the lower bay (Hoekman et al. 2011a, b), population concentrations in 2011 were relatively moderate and centered in protected inlets closer to sources of glacial outflow. However, in contrast to the strong association of KIMU with glacially-influenced habitat elsewhere (Kuletz et al. 2003, Arimitsu et al. 2011, Kissling et al. 2011), the relatively diffuse distribution in 2011 meant most KIMU were not closely associated with tidewater glaciers or glacial outwash. Breeding KIMU populations exhibit high spatial and temporal variability, and whether ephemeral concentrations of murrelets happen to be sampled can dramatically influence population estimates (e.g., Day et al. 2011, Hoekman et al. 2011a). In contrast to many prior surveys (Hoekman et al. 2011a, b; Piatt et al. 2011), we sampled no transects with exceptionally high KIMU densities in 2011, and missing such concentrations in the survey area could have depressed our population estimate. Furthermore, the densest concentrations of KIMU were at the outlet of Scidmore Bay and Charpentier Inlet (just northeast of the legend in Figure 3), which is adjacent to unsampled fjords, suggesting a large portion of the local population could have been unavailable for sampling.

Our surveys allocated sampling effort proportional to expected KIMU densities to improve precision of KIMU population estimates. KIMU encounter rates in 2011 correlated more closely with the expected spatial distribution of densities than in prior surveys, leading to increased benefits from this design.

The majority of MAMU in Glacier Bay during the breeding season typically have been found in the main bay (Drew et al. 2008; Hoekman et al. 2011a, b). Use of the upper arms was unusually high in 2011, but the southern part of the main bay extending south from Sitakaday Narrows received extremely high use. Large daily influxes of murrelets from Icy Strait observed during times of strong tidal currents (Kirchhoff 2008) suggest that many MAMU near the mouth of the bay may be transient residents commuting to forage in Glacier Bay.

Detection and identification

Visual conditions throughout 2011 surveys were improved in comparison to 2009 and 2010, with almost no precipitation (< 1% of observations) or waves > 20 cm (< 5%). Consequently, observers detected many groups at large perpendicular distances from the transect center line, resulting in a large right truncation distance and high estimated detection probability at large distances relative to 2009/2010 surveys (Hoekman et al. 2011a, b). Despite high frequency of observations at large distances, identification rates exceeded those in prior surveys, which we attribute to nearly optimal viewing conditions and relatively experienced observers.

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